

CRITERIA ANALYSIS AIDING PORTFOLIO SELECTION USING DEMATEL

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Abstract

Portfolio analysis is one of the major areas of research in the financial sector, where the uncertainty and dynamism plays a dominant role. Portfolio analysis primarily involves two major aspects: portfolio selection and portfolio optimization. A portfolio may include numerous industries and related companies. The criteria for selection of industries in the portfolio shall be different from the criteria considered for company selection. The application of Multi Criteria Decision Making (MCDM) techniques gains importance in this situation. The paper identifies and evaluates various criteria relevant for companies, which can aid in developing a framework for portfolio analysis. Here the companies listed in National Stock Exchange (NSE) are taken as the basis for the identification of relevant criteria to formulate a portfolio in an Indian context. Thereafter, DEcision MAKing Trial and Evaluation Laboratory (DEMATEL), an MCDM technique is applied to identify the importance and causal relationship among the identified criteria. The findings arrived at are expected to facilitate choice under conflicting multiple criteria scenario for portfolio selection. The results shall also form a base work for portfolio selection model.

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1. Introduction

The term portfolio refers to combination of assets that include stocks, bonds and/or cash. The portfolio may be held by individual investors and/or managed by financial professionals, hedge funds, banks and other financial institutions. A portfolio is designed according to the investor's risk tolerance, time frame and investment objectives.

Portfolio theory and related topics are among the most investigated areas of research in the economic and financial literatures. According to the theory, it is possible to construct an efficient frontier of optimal portfolios offering the maximum possible expected return for a given level of risk [1]. The

essence of portfolio theory is portfolio selection and optimization. The process of selecting a portfolio may be divided into two stages. The first stage starts with observation and experience and ends with beliefs about the future performances of available securities. The second stage starts with the relevant beliefs about future performances and ends with the choice of portfolio [1]. The objective of portfolio optimization is to maximize the yield and simultaneously minimize the risk [2]. The portfolio optimization was first suggested by Harry Markowitz who published the article portfolio selection in *Journal of Finance* (1952). Portfolios are considered mean-variance efficient if they minimize the variance for a given mean return or if they maximize the expected mean return for a given variance [3].

The portfolio selection assumes two vectors associated with each portfolio. The first one is used to define a portfolio which determines the proportion of money to be invested in different securities. The second vector describes the portfolio consisting of the values of measures used to evaluate a portfolio [4]. Regardless of having different techniques for portfolio selection, the selection of portfolio considering stocks from different companies has not been resolved properly. From the literature concerning portfolio selection, the influence of major factors like, market return, risk-free rate and beta were identified to influence the stock returns. The other factors such as production growth, time interest earned, sales growth and so on remain elusive. Different search techniques and heuristics based algorithms have been applied for portfolio selection. In most cases, the computation of objective function is time consuming. Thus, saving computational time is very important in large scaled problems. As portfolio selection considers multiple criteria, various Multi Criteria Decision Making (MCDM) techniques have been used for the evaluation of these. The weights to be attached to each criterion pose a major challenge. Also, the evaluation of stocks from different companies requires different criteria. Most of the methods related to portfolio selection consider only a minimum number of companies as well as criteria.

A portfolio may include numerous industries and related companies. The criteria for selection of industries in the portfolio shall be different from the criteria considered for company selection. Here the companies are considered in an Indian context and hence have used the companies based on the listings from National Stock Exchange (NSE). The criteria identified are evaluated so as to obtain a causal relationship using the MCDM technique called DEcision MAKing Trial and Evaluation Laboratory (DEMATEL).

The paper is organized as follows: Section 2 gives the literature review with regard to portfolio selection and the techniques used for the same. The section also covers an overview regarding the applicability of DEMATEL in various areas. The DEMATEL technique is described in Section 3. In Section 4 the criteria identified for the company evaluation are presented, followed by the application of DEMATEL to identify the importance and causal relationship among the identified criteria. The results and discussions form Section 5, followed by references.

2. Literature review

The uncertain nature prevailing in the area of portfolio analysis has prompted many researchers to think seriously towards this, especially in the present economic scenario. Various techniques have been proposed by authors in the area of portfolio analysis. Some of them have addressed the issue of portfolio selection while some have concentrated on portfolio optimization. Golmohammadi and Pajoutan [5] have applied metaheuristics for dependent portfolio selection problem. The authors have identified that in industrial and constructional projects, the projects face the major problem of dependency between projects. Here the authors use an Electromagnetism-like (EM-like) and a Genetic Algorithm (GA) to solve the problem. It was found that GA has better performance in comparison with EM-like algorithm. Marasovic and Babi [6] used a two stage multi- criteria model for optimal portfolio selection. The model proposed helps to find the choice of different industries to form an overall choice of portfolio for each

industry. This model has been applied at the Zagreb Stock Exchange (ZSE) as a real case. Simulated Annealing (SA) approach has been applied by Crama and Schyns [7] to find solution of a complex portfolio selection model. Abdelaziz et al. [8] has used multi-objective programming techniques such as goal programming (GP) and compromise programming (CP) to choose the portfolio best satisfying the decision maker's aspirations. The method identified is applied in portfolio selection problem from the Tunisian stock exchange market.

Many economic, social, and environmental criteria are nowadays involved in practical decision making situations, to describe the diverse outcomes of the existing choices. The decision process needs to explore the conflicting criteria, the goals set by the decision makers and the way these can be introduced in decision model. MCDM techniques are quite relevant in these circumstances. Zopoundis and Doumpos [9] reviews the multi-criteria aid in financial decision making. The authors highlight the importance of developing and implementing different techniques aiding in financial decision making. Application of such techniques in portfolio optimization is also reviewed. A fuzzy MCDM model was suggested for financial performance evaluation by Yalcin et al. [10]. A hierarchical financial performance evaluation model is structured by Yurdakul and Tansel [11], based on Accounting-based Financial Performance (AFP) and Value-based Financial Performance (VFP). The weights of the criteria are determined by Fuzzy analytic hierarchy process (FAHP). Here, Analytic Hierarchy Process (AHP) technique has been used for credit evaluation, which is usually done by banks to determine if the debts will be paid back by the firms on time. For ranking the entry mode alternatives in firms for foreign direct investment (FDI), Levary and Wan [12] used AHP. Huck [13] used Elimination Et Choix Traduisant la Realite (ELECTRE) for pair selection and outranking of S&P stocks. ELECTRE includes comparison of alternatives with each other in the first stage followed by ranking of the same to obtain the best alternative. Brans and Mareschal [14] provides an elaborate study on the application of Preference Ranking Organisation METHod of Enrichment Evaluations (PROMETHEE) method to select superior stocks in stock exchange. An implementation in Tehran Stock Exchange (TSE) is also illustrated. A comparative study of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) with other multi criteria decision making method was suggested by Opricovic and Tzeng [15].

The present paper deals with the application of DEMATEL in the evaluation of criteria for selection of companies to form a portfolio. The technique called DEMATEL has been applied on various areas. DEMATEL aids to prioritize the alternatives as well as depict the causal relationship between each other. Lee et al. [16] has developed an investment model using DEMATEL and ANP for studying the relationship between several criteria for investment and the factors affecting these criteria. Lee et al. [17] identifies the causal relationship among the order winners and qualifiers in a computer industry. Wu and Lee [18] used DEMATEL to solve an issue of core competencies involved in new business challenges. J. I. Sheih et al. [19] has applied the technique to prioritize the key success factors for the hospital service quality. The procedure for DEMATEL is described in the following section.

3. Decision making trial and evaluation laboratory (DEMATEL)

DEMATEL was developed at the Geneva Research Centre of the Battelle Memorial Institute. DEMATEL provides solution to problems visually and plots a causal relationship map enabling the division of multiple criteria into a cause and effect diagram. The digraph (directed graph) depicts the relationship between each individual with each other proving more useful than directionless graph. The advantages of DEMATEL when compared to other MCDM methods are as follows:

- The technique facilitates the conversion of indirect relation into a cause and effect diagram [20].
- It is an effective method to analyse the overall structure [21].

- The criteria are usually considered mutually independent, according to the traditional multiple criteria decision making techniques; however, DEMATEL technique helps the decision makers in identifying the casual relationships among criteria rather than depending on assumptions.
- The DEMATEL provides a systematic approach in identifying criteria, the relationships, and the weights on which decisions are to be made.
- Usual prioritization methods do not consider indirect relations between components and are deficient for systems with many subsystems or components. DEMATEL is an effective approach for analysing relation between components of a system in respect to its type (direct/indirect) and severity [22].
- With the help of this technique, it is possible to combine individual responses into a total single matrix.

As an illustration of the DEMATEL technique, consider a system with criteria $C = \{C_1, C_2, \dots, C_m\}$ whose pair-wise comparison is to be carried out. The row vector is represented by i and column is represented by j , which consists of different criterion for comparison. The opinions from k experts are taken to estimate the influence of criterion on each other. As many number of opinion matrices as the number of expert review claimed is obtained. A scale such as a Likert's scale is used to determine the extent of influence. The different steps followed in DEMATEL technique are as follows:

Step 1: Obtain the combined matrix.

The varied expert opinion matrices are aggregated to get an overall $n \times n$ non-negative matrix, E_{ij} of the form:

$$\begin{bmatrix} e_{11} & \dots & \dots \\ \dots & \dots & e_{ij} \end{bmatrix} \quad (1)$$

where i represent the row and j represent the column vector . e_{ij} gives the elements of matrix.

Step 2: Find the average matrix.

The average A_{ij} of matrix E_{ij} is computed using the relation:

$$A_{ij} = 1/k \sum_{k=1}^k E_{ij} \quad (2)$$

where 'k' indicates the total number of matrices.

Step 3: Calculate the normalized direct-relation matrix.

The normalized direct-relation matrix is acquired from the following equation:

$$R = A_{ij} * N \quad (3)$$

where 'N' is the normalized baseline and the maximum [11]. According to [21], the column/row vector and the maximum is the baseline, given as:

$$N = 1/\text{Max} \sum_{j=1}^q A_{ij}, \text{ for } 1 \leq i \leq q \quad (4)$$

Step 4: Compute the total relation matrix

The total relation matrix, T can be obtained using the formula

$$T = R (I - R)^{-1} \quad (5)$$

Where I is the identity matrix, R is the normalized direct relation matrix.

Step 5: Obtain the causal relation.

Let r_i and c_j be the i^{th} row and j^{th} column of the total relation matrix T . The sum $(r_i + c_j)$ denotes the level of importance element i has in the entire system when $i = j$. However, $(r_i - c_j)$ indicates the net effect of element i when $i = j$. When the difference is positive, it gives the net cause and if negative, it gives the net effect. A graph is plotted with $(r_i + c_j)$ values along x-axis and $(r_i - c_j)$ values along y-axis.

Step 6: Set a threshold value and obtain the digraph.

Usually threshold value is set by conducting interviews with experts as illustrated in [11], [21]. This is incurred to reduce complexity of the relationship mapping. In the work suggested by J. I. Sheih et al. [19], the service quality of hospital is identified by comparing the criteria chosen, based on DEMATEL. Here the authors have obtained the average of the total relationship matrix as the threshold value. The digraph giving causal relationship among criteria is figured out.

Step 7: Obtain the causal matrix

The matrix has four quadrants represented as I, II, III and IV. x- axis gives the importance (low/ high) of criteria and their net relation (low/ high) is plotted along y-axis. Low relation indicates the criterion serves as an effect rather than being a cause and vice-versa, when the relation is high. The inferences to be made from quadrants are:

1. Quadrant I is of high importance and high relation. Criteria along this area are essential which may influence other criteria. So they need to be managed immediately.
2. Quadrant II is of low importance and high relation. Criteria in this area are independent and affect others by very less amount.
3. Quadrant III is of low importance and low relation. Criteria in this region are also independent and getting affected by some other criteria is of very little chance.
4. Quadrant IV is of high importance and low relation. This shows that criteria in this area are also essential ones as in quadrant I but these are affected by others. So, these factors also need to be dealt with initially.

4. Application of DEMATEL in criteria evaluation

Initially it is required to identify the various companies that could form a part of the portfolio. The various criteria that can be applied for evaluation of these companies also need to be listed. Application of DEMATEL reduces the number of criteria to evaluate the effectiveness of the portfolio. Analysing the causal relationship among varied criteria, they can be divided into cause and effect groups. Thus, the researchers can better understand the structural relationship between criteria, which help them to utilize these criteria in a better manner for company evaluation. This is elaborated as follows:

4.1 Selection of companies which can be part of the portfolio.

Here the companies are selected based on an Indian context. The companies listed in the National Stock Exchange (NSE) have been taken, as it is regarded to be the pulse of the Indian stock market. Though there were 56 industries listed in NSE, based on expert opinion, 22 most active industries among them were selected considering an one year performance (June 2010- May 2011). Further, the companies belonging to these best performing industries were selected for criteria evaluation.

4.2 Identification of criteria for company evaluation.

Albadvi et al. [23] provides different criteria which are quite relevant. The same were initially considered for the company evaluation. An overview on these criteria and their influence on Indian economy were

identified. Further, an expert review from the investment organizations including the Stock Holding Corporation Limited (SHCL), Geogit securities and suggestions from the economic experts were obtained. Based on the reviews, a set of 9 criteria were finally chosen for the company evaluation. These are: Total assets turnover rate, Price to earnings ratio, Beta coefficient, Book value, Competition in industry, Time interest earned, Liquidity ratio, Production growth and Sales growth.

- **Total assets turnover rate**

Assets are the economic resources capable of being owned and the owned value can be converted into cash. The balance sheet of a firm records the monetary value of the assets owned by the firm. It is the money and other valuables belonging to an individual. Two major asset classes are tangible assets and intangible assets. Tangible assets include current assets and fixed assets. Current assets include inventory, while fixed assets include items such as buildings and equipment. Intangible assets include goodwill, copyrights, patents, computer programs and financial assets. Total asset turnover is the ratio between revenue to the total assets. Companies with high profit margin tend to have lower turnover rate and vice-versa. Revenue of a firm is the sum of number of total sales obtained from a company's income statement. The total assets can be obtained from the balance sheet. The total asset turnover rate helps a company to know if the sales are generated from the investments made by the company. The data provides an indication with regard to management of assets.

- **Price to earnings ratio(P/E ratio)**

P/E is the ratio of a company's share price to its per-share earnings. To calculate the P/E ratio, the current stock price of a company is divided by its earnings per share (EPS). EPS is usually taken from the last four quarters (trailing P/E), but sometimes it can be taken from the estimates of earnings expected in the next four quarters (projected or forward P/E). Most of the traders and investors depend on the P/E ratio. The P/E ratio shows whether the stock's price is high or low compared to its forward earnings. The P/E ratio gives an idea of what the market is willing to pay for the company's earning. The P/E ratio shows the hope; a market has on the company. The higher the P/E, the more the market is willing to pay for the company's earning. Investors try to find low P/E ratios stocks of high value growth companies and make investments in such stocks, which may prove to be worthy in future.

- **Book Value**

The value at which an asset is carried on a balance sheet is called Book value. It is calculated by subtracting the accumulated depreciation from the cost of an asset. Usually, a company's book value is its total assets minus intangible assets and liabilities. However, depending on the source of the calculation, book value may variably include goodwill, intangible assets, or both. The total value of the company's assets that shareholders would theoretically receive if a company was liquidated is a company's book value. Getting compared to the company's market value, the book value can indicate whether a stock is underpriced or overpriced. The major factors influencing book value include exchange rates, new equity financing, acquisitions, accounting policy changes and restructuring provisions and write-offs [24].

- **Beta coefficient**

The volatility of a security or of an investing portfolio of securities is measured in comparison with the market as a whole by the Beta coefficient [25]. The sensitivity of a stock's returns to the returns on market index is calculated by beta. It is calculated using regression analysis. Beta of one indicates that the security's price will move with the market. A beta greater than one indicates that the security's price will be more volatile than the market and less than one means that it will be less volatile than the market. Most of the upcoming new high-tech stocks have a beta greater than one. They offer a higher rate of return but they are also very risky. The more risky a stock is, the more its beta moves upward. A low-beta stock will protect in a general worsening of business or economic activity. However, the beta measure keeps changing over time [25]. Beta is a good company evaluation tool for investors trying to buy and sell stocks within short span of time even though it remains less important for investors with long term investment goals.

- Competition in industry

Competition arises whenever at least two parties strive for a goal which cannot be shared. It may occur between individuals or groups for territory, a niche, or a location of resources [26]. Most companies are in competition with at least one other firm over the same group of customers. The key element of a market economy is competition. Different firms producing similar products provide choice to consumers. Governments intervene to regulate the behaviour of companies so that they cannot unfairly manipulate prices and gain excessive levels of profit which may be disadvantageous to consumers [26]. The competition for a particular company can be evaluated by the market shares held by various companies competing in a particular industry.

- Time Interest Earned

Times interest earned (TIE) or interest coverage ratio is a measure of a company's ability to honour its debt payments. It may be calculated as either Earnings Before Interest and Taxes (EBIT) or Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) divided by the total interest payable [26]. When the company is not generating enough cash from its operations, the interest coverage ratio is smaller than one. It is an indicator that tells whether a company is running into financial trouble. A high ratio means that a company is able to meet its interest obligations because earnings are significantly greater than annual interest obligations. However, if a company pays down too much debt with earnings that could be used for other investment opportunities to get higher rate of return, then also a high ratio is generated. A lower time

interest earned ratio means fewer earnings are available to meet interest payments. A low rate ensures that it will cost less to get the needed financial resources to start or expand a business. Businesses are influenced by the interest rate which measure the general cost of doing business. If this rate rises, so does the cost of maintaining a business, which in turn necessitates higher prices for products and services. Lower rates indicate that people have more disposable income to spend [27].

- Liquidity ratio

Liquidity refers to how fast something can be turned into cash. Liquid assets are those that are thought to be turned to cash immediately. Different analysts consider different assets to be relevant in calculating liquidity [27]. A company's ability to turn short-term assets into cash to cover debts is of the utmost importance when creditors are seeking payment. Company's liquidity may vary due to seasonality, the timing of sales and the state of the economy. Liquidity ratios helps in regulating the borrowing and spending. Start up companies are often not very liquid. A low level of liquidity indicates poor management or a need for additional capital. Some of the best-known measures of a company's liquidity are as follows [27][28] :

- Current ratio

Is the ratio of Current assets to Current liabilities. Current includes that within one year. The company may not be able to pay its bills on time with a lower current ratio while a higher ratio means that the company has money for safe investment.

- Quick assets ratio

It is the ratio of cash, marketable securities, and receivables to the Current liabilities. Higher the quick assets ratio, the company may keep too much cash on hand and if it is lower, it may indicate that the company relies on inventory to meet its obligations.

- Cash to total assets ratio

It is the measures of the portion of a company's assets held in cash or marketable securities. A high ratio may indicate some degree of safety while excess amounts of cash may be viewed as inefficient.

- Sales to Receivables ratio (Or Turnover Ratio)

It is the ratio of Net sales to Accounts receivable. Higher the ratio, there is a short lapse of time between sales and the collection of cash, while a low ratio means collections takes longer time.

- Day's receivables ratio

It gives the measure of the average number of days that accounts receivable are outstanding. This number should be the same or lower than the company's expressed credit terms. Cost of sales to payables ratio
The annual turnover of accounts payable is given by this ratio. Lower ratio indicates good performance, though the ratio should be close to the industry standard.

- Cash Turnover ratio

It is the ratio of Net sales to Net working capital. This reflects the company's ability to finance current operations, the efficiency of its working capital employment and the margin of protection for its creditors. A low ratio may indicate an inefficient use of working capital.

• Production growth

Productivity can improve as firms move toward the best available technology. Firms can change organisational structures, management systems and work arrangements to take the best advantage of new technologies and changing market opportunities. Production growth originates from a complex interaction of factors [28]. Some of the most important factors include technological change, organisational change, industry restructuring and resource reallocation as well as economies of scale and scope. Other factors such as research and development and innovative effort, the development of human capital through education and incentives from stronger competition promote the production growth to greater heights. Economic factors affecting businesses are regulation, access to credit, demand for goods and/or services and technological advancement [28].

• Sales growth

The increase in sales over a specific period of time, often but not necessarily indicate the annual sales growth. It can be calculated as the ratio of difference between current period's sale and previous period's sale to the previous period's sale, wherein if (h) be the current period's sale, then (h-1) is the previous period's sale. The marketing strategies are realized by taking the consumer concept with respect to the point of sale. Different ways to increase sales growth are by setting up sales incentive programs, encouraging sales staff to up sell, giving customers the inside scoop, setting up a customer rewards program and distributing free samples to customers.

It will be interesting to analyse the cause and effect nature of these criteria and its usefulness in the evaluation of companies for making it a part of the proposed portfolio. As various individuals and investment agencies might have different priorities for these criteria in the evaluation of companies, DEMATEL can be a useful technique for converging the priorities of different agencies.

4.3 Application of DEMATEL

The general steps of DEMATEL technique provided in section 3 are illustrated for the criteria evaluation scenario as follows:

Step 1: Obtain the combined matrix.

As per the previous section, altogether nine criteria were shortlisted based on the expert reviews. A 4-point Likert's scale was chosen to determine the influence of each criterion with respect to one another: 1- No influence on criteria, 2- Low influence on criteria, 3- Medium influence on criteria and 4- High influence on criteria. Various 9x9 opinion matrices were obtained based on the views of experts. These were combined to give a single 9x9 non-negative matrix E_{ij} :

$$\begin{bmatrix} 5 & 10 & 17 & 17 & 18 & 18 & 10 & 12 & 12 \\ 10 & 5 & 16 & 18 & 10 & 14 & 19 & 17 & 19 \\ 12 & 16 & 5 & 17 & 17 & 18 & 18 & 16 & 19 \\ 15 & 11 & 18 & 5 & 15 & 18 & 20 & 16 & 16 \\ 18 & 10 & 17 & 18 & 5 & 10 & 18 & 20 & 12 \\ 20 & 17 & 10 & 16 & 12 & 5 & 10 & 17 & 17 \\ 12 & 11 & 17 & 17 & 19 & 10 & 5 & 16 & 13 \\ 10 & 11 & 16 & 15 & 17 & 18 & 20 & 5 & 10 \\ 15 & 20 & 17 & 17 & 10 & 19 & 16 & 10 & 5 \end{bmatrix}$$

Step 2: The average matrix A_{ij} , found using equation (2) is as follows:

$$\begin{bmatrix} 1 & 2 & 3.4 & 3.4 & 3.6 & 3.6 & 2 & 2.4 & 2.4 \\ 2 & 1 & 3.2 & 3.8 & 2 & 2.8 & 3.8 & 3.4 & 3.8 \\ 2.4 & 3.2 & 1 & 3.4 & 3.4 & 3.6 & 3.6 & 3.2 & 3.8 \\ 3 & 2.2 & 3.6 & 1 & 3 & 3.6 & 4 & 3.2 & 3.2 \\ 3.8 & 2 & 3.4 & 3.6 & 1 & 2 & 3.6 & 4 & 2.4 \\ 4 & 3.4 & 2 & 3.2 & 2.4 & 1 & 2 & 3.4 & 3.4 \\ 2.4 & 2.2 & 3.4 & 3.4 & 3.8 & 2 & 1 & 3.2 & 2.6 \\ 2 & 2.2 & 3.2 & 3 & 3.2 & 3.6 & 4 & 1 & 2 \\ 3 & 4 & 3.4 & 3.4 & 2 & 3.8 & 3.2 & 2 & 1 \end{bmatrix}$$

Step 3: The normalized direct-relation matrix was calculated.

The normalized baseline and the maximum, N , was obtained using equation (4) as 0.0532. Now, from equation (3), the normalized direct-relation matrix R is:

$$\begin{bmatrix} 0.0362 & 0.0724 & 0.1231 & 0.1231 & 0.1303 & 0.1303 & 0.0724 & 0.0869 & 0.0869 \\ 0.0724 & 0.0362 & 0.1158 & 0.1376 & 0.0724 & 0.1014 & 0.1376 & 0.1231 & 0.1376 \\ 0.0869 & 0.1158 & 0.0362 & 0.1231 & 0.1231 & 0.1303 & 0.1303 & 0.1158 & 0.1376 \\ 0.1086 & 0.0796 & 0.1303 & 0.0362 & 0.1086 & 0.1303 & 0.1448 & 0.1158 & 0.1158 \\ 0.1376 & 0.0724 & 0.1231 & 0.1303 & 0.0362 & 0.0724 & 0.1303 & 0.1448 & 0.0869 \\ 0.1448 & 0.1231 & 0.0724 & 0.1158 & 0.0869 & 0.0362 & 0.0729 & 0.1231 & 0.1231 \\ 0.0869 & 0.0796 & 0.1231 & 0.1231 & 0.1376 & 0.0724 & 0.0362 & 0.1158 & 0.0941 \\ 0.0724 & 0.0796 & 0.1158 & 0.1086 & 0.1158 & 0.1303 & 0.1448 & 0.0362 & 0.0724 \\ 0.1086 & 0.1448 & 0.1231 & 0.1231 & 0.0724 & 0.1376 & 0.1558 & 0.0724 & 0.0362 \end{bmatrix}$$

Step 4: The total relation matrix (T) was computed.

T , obtained using the equation (5) is given as follows:

1.1363	1.1041	1.3413	1.4068	1.2621	1.3219	1.3713	1.2789	1.2233
1.2533	1.1512	1.4324	1.5204	1.3002	1.3912	1.5344	1.4019	1.3573
1.3434	1.2950	1.4416	1.5964	1.4215	1.4965	1.6151	1.4782	1.4344
1.3250	1.2273	1.4859	1.4719	1.3727	1.4560	1.5811	1.4373	1.3759
1.3036	1.1753	1.4320	1.5055	1.2613	1.3579	1.5169	1.4138	1.3023
1.2695	1.1840	1.3400	1.4445	1.2613	1.2782	1.4169	1.3480	1.2927
1.1903	1.1169	1.3531	1.4170	1.2788	1.2797	1.3492	1.3136	1.2370
1.1817	1.1206	1.3480	1.4079	1.2631	1.3318	1.4487	1.2441	1.2222
1.3302	1.2918	1.4869	1.5607	1.3460	1.4692	1.5981	1.4067	1.3124

Step 5: The causal relation was obtained.

The total and net effect of criterion i is summarized in Table 1.

Table 1: The importance and relation of criteria

Element i (Criteria)	$(r_i + c_j)$ (Importance level)	$(r_i - c_j)$ (Net cause and effect)
Time interest earned	22.7793	0.1127
Total asset turnover rate	23.0085	1.6761
Production growth	25.7833	0.4609
Sales growth	26.0642	-0.5980
Price/Earnings ratio	24.0365	0.5025
Liquidity ratio	24.2175	-0.5473
Competition in industry	24.7673	-1.6961
Beta coefficient	23.8906	-0.7544
Book value	24.5595	1.0445

Based on $(r_i + c_j)$ values, the importance of 9 criteria for company evaluation can be prioritized as follows:

- Sales growth (SG)
- Production growth (PG)
- Competition in industry (CI)
- Book value (BV)
- Liquidity ratio (LR)
- Price/Earnings ratio (P/E R)
- Beta coefficient (BC)
- Total asset turnover rate (TATR)
- Time interest earned (TIE)

$(r_i - c_j)$ values suggest the direct impact of criterion on each other. The positive values indicate the net causes. Hence the criteria which remain as net causes are-

- Time interest earned
- Total asset turnover rate

- Production growth
- Price/Earnings ratio
- Book value.

Depending on negative values of $(r_i - c_j)$, the criteria which serves as net effects are-

- Sales growth
- Liquidity ratio
- Competition in industries
- Beta coefficient.

Step 6: A threshold value was set and obtained the digraph.

The threshold value was set by taking the average value of the total relation matrix, which is motivated by the procedure followed in [19]. The threshold value was obtained to be 1.3537. All those values below threshold were excluded when constructing the digraph. The digraph giving causal relationship among criteria for industrial evaluation is given as Fig.1.

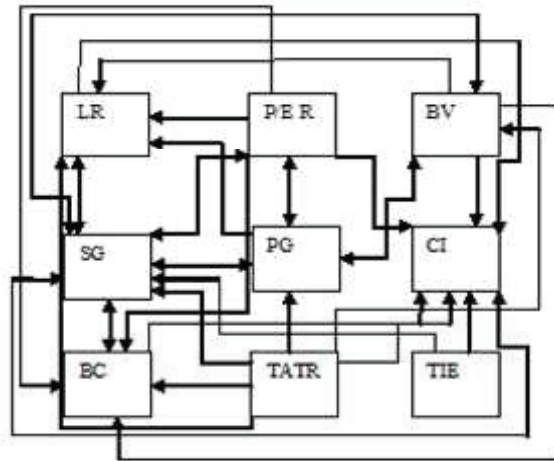


Fig. 1: The Digraph

Step 7: The causal matrix was obtained.

The matrix as described in step 7 of section 3 was obtained and is plotted as Fig.2.

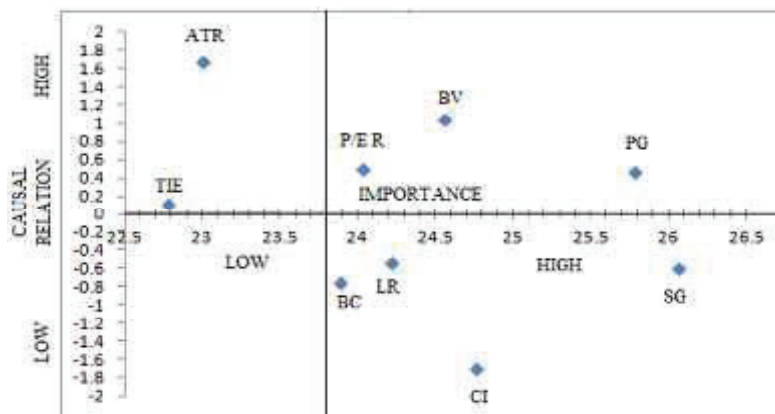


Fig. 2: Causal relation matrix

5. Results and discussions

The criteria for company evaluation, converged after the review of experts, were prioritized using DEMATEL. The digraph and causal relation matrix among criteria were also obtained. In a technologically oriented and market savvy society, productivity and sales are the major contributors to firm growth. This was evident from the fact that sales growth assumes paramount importance followed by production growth and competition among the firms. So focusing on these criteria makes a positive impact on investor's mind as regards selection of a particular firm as part of their portfolio. This is true especially in case of Indian economy as seen from the recent developments. The production growth, price-to-earnings ratio and book value is found to have substantial influence on the performance of various companies in the stock markets. However, these remain as the net causes while sales growth, liquidity ratio, competition in industries and beta coefficient serve as net effects. The same is obtained while considering the $(r_i + c_j)$ and $(r_i - c_j)$ values. Sales growth, production growth and competition in industry are those criteria, which if taken pairwise are found to be mutually dependent/influenced.

Asset turnover rate and time interest earned plays a limited role, when the formulation of portfolio with companies is considered. However, book value, price-to-earnings ratio and production growth are of high importance and high causal relation. Thus, these criteria need to be addressed while making an evaluation of the companies. Liquidity ratio and beta coefficient are also of high importance for company evaluation but they serve as net causes with lower causal relation.

Here various criteria for evaluation of companies to form a portfolio have been analysed in an Indian context. The criteria were prioritized and the causal relationships among them were studied using the technique of DEMATEL. The proposed application of DEMATEL in portfolio selection is a universal method which can be applied to all portfolios confronting problem in decision making where it is desired to converge the decision based on multiple opinions. The importance and causal relationships for various criteria obtained here can be taken as a base for portfolio modelling and optimisation, considering individual investor preferences and constraints as well as market restrictions. For future research, the same method may be applied for undertaking industry or sector wise evaluation, so as to evolve a combined model, wherein one can obtain the best industries and thereby obtain the best performing companies within that industry.

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